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DEVIATION IN DEVELOPMENT DUE TO THE USE OF UNRIPE SEEDS.[1]

BY J. C. ARTHUR.

There is something surprising in the degree of immaturity at which seeds will grow. The usual opinion is, I believe, that seeds not fully ripe will be shrunken and light, and quite worthless for sowing. To some extent there is truth in this, and yet seeds will vegetate when taken from fruit not half grown, and in which the pulp and even the seeds themselves have the color of fresh, green leaves. Plants from such seeds may flourish, bloom and fruit, and with a certain moderate amount of deviation, show all the usual phases of existence incident to the particular kind of plant life.

This is by no means a recent discovery, but was known to Theophrastus,[2] as early as the third century before Christ, who expressed his surprise at the fact, and says that it is wonderful that unripe, imperfect seeds should be able to grow. The fact was established experimentally, however, by several early investigators, notably by Duhamel,[3] in 1760, using flowering ash and walnut, by Senebier,[4] in 1800, using peas, and by Lefebure,[5] in 1801, using radish. In 1822 a successful trial with green seed was made by Seyffer,[6] of Stuttgart, which has attracted much attention. The Japanese Sophora, although growing to be a fine tree in Germany, does not often set fruit, and never ripens any, at least in Würtemberg, on account of the cool summers. Despairing of ever securing ripe seed from which to propagate the tree, Seyffer took a branch bearing green fruit, not yet half full size, hung it up until dry, then removed and planted the seed in a cold frame. In this way he obtained 500

[1] Read before the section of botany of the A. A. A. S., Madison meeting, August, 1893.

[2] De causis plantarum, lib. iv., cap. 4.

[3] Duhamel du Monceau, Des semis et plantation des arbres, p. 83.

[4] Senebier, Phys. végétale, iii, p. 377.

[5] Lefebure, Expériences sur la germination des plantes, p. 27.

[6] Seyffer, Isis, 1838, p. 113.

young plants, many of which still were to be seen as handsome trees in the grounds of the forestry school at Hohenheim, and in the vicinity, sixteen years afterward, when the paper from which we quoted was read. The economic importance of such a procedure, and its applicability to numerous contingencies, has brought the incident much well merited attention.

It would be possible to cite many other instances[7] of the successful germination of green seed, but it is unnecessary, for all doubt regarding the viability of such seed was set at rest long ago in the very exhaustive treatise upon the subject by Ferdinand Cohn, entitled, "Symbola ad seminis physiologiam," 1847, in which he not only reviewed the previous history, but also himself grew plants of more than a score of widely diverse species from seed in various stages of immaturity.

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[7] Waitz, with morning glory (Convolvulus Nil) Bot Zeit , 1835, p. 5.

Kunze, with wheat. Bot. Zeit., 1835, p. 5.

Kurr, with rye (?), ten-weeks-stock. Bot Zeit., xviii (1835), p. 4.

Seyffer, with peas, kidney beans (Phaseolus vulgaris), English beans (Vicia Faba), soja beans, lentils, laburnum, Sophora Japonica. Bot. Zeit., 1836, p. 84; Isis, 1838, p. 5.

Treviranus, with turnips and peas. Physiologie der Gewächse, ii (1838), p. 576.

Göppert, with rye. Bot. Zeit., v (1847). p. 386.

Cohn, with beans (Phaseolus vulgaris), lupines, radish, shepherd's purse, corn, sorghum, datura, apple, cucumber, canna, evening primrose, princes' feather (Amarantus caudatus , morning glory, (Ipomœa purpurea), Salvia verbascifolia, pinks, squirting cucumber (Momordica Elaterium), bladder senna Colutea arborescens), marshmallow (Althæa officinalis), castor bean. Symbola ad seminis physiologiam, 1847; Flora, xxxii (1849), p. 481.

Lucanus, with rye. Landw. Vers.-St., iv (1860), p. 262.

Siegert, with wheat. Landw. Vers.-St , vi (1863), p. 134.

Nowacke, with wheat. Untersuchungen über das Reifen des Getreides, 1869, p. 37.

Nobbe, with spruce (Picea vulgaris). Tharander forstl. Jahrbuch, xxiv (1874), p. 203; Landw. Vers.-St., xvii (1876), p. 277; Handbuch der Samenkunde, 1876; p. 338.

Sagot, with wheat (?). Arch. des. Sci. Phys. et Nat, 1876; Just's Bot. Jahresb, iv, p. 1243.

Tautphöus, with rye. Ueber die Keimung der Samen, 1876, p. 23

Wollny, with winter rye. Forsch. Geb. Agrik.-Phys., ix (1886), p. 294.

Sturtevant, with maize. Rep., N. Y. Exper. Sta , ii (1883), p. 39.

Goff, with tomatoes, peas, turnips, lettuce. Rep. N. Y. Exper. Sta., ii (1883), p. 205; iii (1884), pp. 199, 211, 224, 232; iv (1885), pp. 130, 182; v (1886), p. 174, 197.

Atwell, with morning glory (Ipomœa purpurea). Bot. Gaz., xv (1890), p. 46; Bot. Centr.. xlvi (1891), p. 162.

Bailey, with tomato. Bull. Cornell Exper. Station, No. 45. 1892, p. 207.

At the very beginning of the agitation of the subject, a curious misusage in terminology arose, which at one time led to considerable controversy, but which gradually disappeared with the better elucidation of the subject. The confusion was in regard to the application of the terms viability, or power of germination, and maturity, or ripeness. The implied reasoning of most writers, especially the earlier ones, seems to have been this: The object of maturity is to render the seed capable of becoming an independent plant through germination, therefore a seed must be mature before it can germinate, *per contra*, the seed that germinates has already reached maturity.

In Gærtner's monumental work on seeds and fruits, published in 1790, is the statement[8] that seeds are ripe as soon as they can germinate, although from their color, weight and size, they may not appear so. Senebier,[9] in the year 1800, held that seeds must be ripe in order to grow, and yet at the same time says that he has seen green tender peas, taken from equally green pods, germinate. The same confusion of ideas is shown in the defense which Keith made when DeCandolle[10] pointed out that it was an error to place maturity of the seed as one of the conditions for germination, as Keith[11] had done in his work on vegetable physiology, published in 1816. Keith[12] says: "The seed that will germinate is, physiologically speaking, ripe; that is, its fluids have been so elaborated in the process of its maturation, and its solids so vitalized in the assimilation of due aliment as to be now fully and profitably susceptible of the action of the combined stimuli of the soil and atmosphere. Hence I contend, notwithstanding the objection of M. DeCandolle, that the maturity of the seed is rightly and legitimately placed in the list of the conditions of germination." Treviranus[13] held essentially the same views, and expressed himself quite as strongly in his work on vegetable physiology, about the same time. Even Cohn, in his clear and scholarly paper, did not quite set the matter straight. He came to the conclusion,[14] that although the proper ripening of the seed is dependent upon the parent plant, yet when prematurely separated it will still pass through the ripening stage before germinating; there is thus an after-ripening for green seeds, which fits them for continued growth. Although he seemingly held that seeds cannot germinate until they in some way ripen, yet he asserted (and it is a most important deduction, correctly worded) that viability does not usually coincide with maturity, but precedes it.[15]

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[8] "Semen maturum, ut docet, non ex colore suo saturato, nec ex sua in aqua subsidentia, neque etiam ex duritie sua satis tuto cognoscitur; sed certior maturitatis nota ex ipso trahenda est nucleo; quippe que, si ex gelatinosa sensim factus sit solidiusculus, si testæ suæ cavitatem repleat exactissime, atque si intra se ipsum nullum prorsus contineat spatium vacuum, indubitatissimum præbit seminis maturi signum quia ita conformatum, germinando aptum est, quæcunque etiam fuerit reliqua ejus conditio." Gærtner, De fructibus et seminibus plantarum, ii (1790), I, p. cxii.

[9] "Les graines doivent être mûres pour germer; pour l'ordinaire elles ne germent pas quand on les a cuillies avant leur maturite; j'ai pourtant vu germer des pois verts and tendres otes de leurs siliques vertes and molles." Senebier, l. c. iii, p. 377.

[10] Phys. Veg., ii (1832), p 662.

[11] Keith, System of vegetable physiology, ii (1816), p. 3.

[12] Phil. Mag., viii (1836), p. 492.

Since the time of Cohn the terminology adopted has agreed well with the facts. The present usage is presented in Nobbe's large and excellent treatise upon seeds. He says:[16] "The continued life of the embryo is not dependent upon the completion of the storing of reserve material in the seed; the power of germination appears much earlier, even in a stage of development of the seed undoubtedly to be designated as 'unripe.'

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[13] "Zum keimen gehort, dass der Same reif sei; das heisst, das der Embryo in dem Grade entwickelt sei, dass er von der Mutterpflanze getrennt, unter Aneignung des Vorrathes nährender Materie im Perisperm oder, in den Samenlappen für sich fortleben kann." Treviranus, l. c., ii, p. 574.

[14] Quum maturatio seminis propria non afficiatur a planta, sumendum videtur, ut etiam processura sit, semine soluto a planta; vel, ut postmaturari possint semina. Cohn, l. c, p. 72.

[15] Facultas germinandi non in idem tempus coincidere solet cum maturitate; hanc illa præcedit Cohn, l. c., p 73.

[16] Die Lebensfähigkeit des Embryo ist an die Vollendung der Reservestoff-Aufspeicherung in Samen nicht gebunden. Die Keimfähigkeit tritt weit früher, schon in einem unzweifelhaft als "unreif" zu bezeichnenden Entwicklungsstadium des Samen ein. Nobbe, Samenkunde, p. 339.

Wiesner[17] has given a concise definition. "The condition," he says, "in which a seed loosens itself from the plant in order to continue its development independently, is designated as maturity." We are, therefore, to regard maturity as applying to the seed as a whole, and viability as applying to the embryo, the physiological processes associated therewith being quite distinct. After-ripening, which takes place when partly grown seed is separated from the parent plant, only leads to partial maturity.

It is an inquiry full of interest as to the minimum development at which a seed will germinate. Goff,[18] in 1884, planted tomato seed in March in boxes in the greenhouse, saved the previous season from fruit still thoroughly green, and obtained only 2 per cent of vegetation. But seed from fruit of full size, and which had begun to lose its green color, although not yet showing any tinge of redness, vegetated 84 per cent, while from fruit with a faint reddish tinge the percentage of vegetation reached 100. In another experiment he found[19] that peas planted in the usual manner in the open ground in April, that had been gathered when in the condition best suited to table use, gave only 3 per cent of vegetation, while those just past this stage of edible maturity gave 9 per cent. But in all probability the conditions of growth at the time were not particularly favorable, as fully ripe seed in the same experiment gave only 54 per cent. of vegetation. In a very carefully conducted experiment with wheat made by Nowacki, selected seed saved from grain when in the milk gave 92 per cent of vegetation, and from grain when turning yellow, as well as when fully ripe, gave 100 per cent., the seed being sown in the open ground (see table III.) Nobbe[20] found that seed of Spruce (*Picea vulgaris* Lk.) gathered on the first and fifteenth of each month from the middle of July to the first of November, and tested in the laboratory in the following January, gave increased percentage of germination according to degree of maturity (see table I). In experiments performed by myself in 1889 tomato seed from green and ripe fruit of the previous season, tested in April in the laboratory, gave 60 per cent germination for the immature seed against 100 per cent for the fully mature. Considerable other data are on record, all going to show that seeds are more certain to germinate the nearer they approach to maturity, or conversely, the more immature the seed, the less number of chances for its germination.

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[17] Der Zustand, in welchem ein Same sich von der Pflanze loslöst, um sich selbständig weiterzuentwickeln, wird als Reife bezeichnet. Wiesner, Biologie der Pflanzen, 1889, p. 40.

[18] L. c., iii, p. 224.

[19] L. c., iii, p. 232.

[20] L. c.

I.—GERMINATION OF SPRUCE SEEDS AT DIFFERENT STAGES OF MATURITY.

Experiment conducted by Nobbe.

Spruce seed, gathered July 15, gave 0 per cent germinations.
Spruce seed, gathered Aug. 1, gave 40.8 per cent germinations.
Spruce seed, gathered Aug. 15, gave 61.2 per cent germinations.
Spruce seed, gathered Sept. 1, gave 75.3 per cent germinations.
Spruce seed, gathered Sept. 15, gave 71.6 per cent germinations.
Spruce seed, gathered Oct. 1, gave 84 5 per cent germinations.
Spruce seed, gathered Nov. 1, gave 88.2 per cent germinations.

The internal examination of the seed to determine the actual stage of development, in connection with such studies, has been rarely attempted. Seyffert and Cohn agree, however, that with such seeds as peas, beans, lentils, canna and evening primrose, the embryo must be sufficiently formed to be detected with a hand lens, in order that the seed should be capable of growth. If the embryo is watery and unformed, according to these observers, the seed will not germinate.

Probably most of us would at first think, as Cohn[21] did, that "it is a curious circumstance in this connection, that while in the ripening of the seed innumerable stages are run through, passing one into the other without interruption, in germination, which is as it were a function of maturity, no transition exists. For evidently a seed can only either germinate or not germinate; there can be no third course." But this is very fallacious reasoning, and is founded upon a misunderstanding of the nature of the seed. In the first place germination is not, even constructively, a function of maturity, as it readily occurs both before and after maturity. From our present standpoint, in whatever way the earlier writers may have viewed the matter, a seed is simply a young plant enclosed in a protective covering derived from the parent plant, and accompanied by surplus nutriment. The resting condition of a seed is purely incidental and designed to aid in distribution and in guarding the plant against injury while very young. From the time of the first cell division in the forming embryo until the new individual becomes established as a free growing plant, there need be no check in the continuous growth, except through untoward conditions, or inherent tendency to provide for such conditions. The germination of seeds inside the fruit of oranges, and gourds, and the ready growth of the mangrove, are familiar instances where the resting period has been practically evaded, and development of the plantlet has been nearly or quite continuous

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[21] Es zeigt sich hierbei der eigenthümliche Umstand, dass während bei der Reife der Same unzählige, ohne Unterbrechung in einander übergehende Stufen durchläuft, bei der Keimfähigkeit, die gleichsam Function der Reife ist; kein Uebergang existirt. Denn offenbar kann ein Same nur entweder keimen, oder nicht; ein drittes giebt es nicht. Cohn, Flora, xxxii (1849), p. 500.

In the growth of green seed we have a case where an attempt is made to give the plantlet the conditions for continued development without passing through the full protective stage. There is nothing in the nature of things, except the want of skill, to prevent the plantlet being removed from the parent plant at any point in its early development, even before its organs can be detected, and by supplying it with the necessary nutriment, heat and moisture, and protecting it against the inroads of destructive organisms (bacteria, molds, etc.), securing to it by these artificial means the conditious for uninterrupted growth, with the entire omission of the usual resting stage.

With this view of the subject it is easy to explain why green seed generally gives fewer germinations as a rule than mature seed; the more exacting conditions for its growth are not well met. And, further, it is evident that Cohn's aphorism that a seed can only germinate or not germinate is saying that a seed can continue to grow or not continue to grow, and is thus robbed of all its mysticism.

To fully understand the problem before us it will be well to inquire into the meaning of maturity. In the course of normal development of the seed the testa becomes more firm and less permeable, the organic constituents of the cells are transformed into solids.or semi-solids, there is a loss of water, growth finally ceases, the organic connection with the parent plant is severed, and the seed is ripe. It remains in an inactive, dormant condition a longer or shorter time and then germinates. Maturity is reached in this metamorphosis when the protecting testa, or pericarp, as the case may be, has become sufficiently solid, and the inner parts sufficiently advanced to permit separation from the parent plant without endangering the life of the embryo.

A most curious thing in connection herewith is the fact that the seed, and sometimes the associated parts of the fruit, will continue to develop under circumstances which put a stop to all growth in the vegetative parts of the plant. If a branch is severed from a tree, all growth in its buds and leaves ceases at once, it wilts, and shortly dies. But the fruits and seeds attached to it continue to develop, and will so continue as long as sufficient moisture remains to transport what food material exists, from the leaves and stem into the fruit and seed. This process is known as after-ripening. So far as I know, it has not been intimately investigated, but I am inclined to think that during this process the embryo continues in actual growth, forming new cells, and elaborating its organs, but that little or no growth takes place in the surrounding parts, although great chemical changes and accumulation of substances do occur.

It was observed by Cohn,[22] who was the first to note such phenomena, that green seeds entirely removed from the fruit and laid in moist earth or sand passed through the various changes of color of normal ripening. If very young, they did not progress far, but if sufficiently grown, although still perfectly green in color, they underwent the intermediate changes, and finally gave every appearance of full, mature seeds. He experimented with the seeds of apple, pear, beans, lupines, Amarantus caudatus, Polygonum tartaricum, Colutea arborescens, Kœlreuteria paniculata, and Canna orientalis. An experiment in after-ripening by Lucanus,[23] is very instructive (see table II). He gathered rye in five stages of maturity, ranging from very small kernels, not yet milky, up to fully ripe kernels. Each collection was separated into four lots; in the first the kernels were removed from the heads at once, in the second, they were allowed to remain in the heads, but the heads were removed from the stalks; in the third they remained attached to the plant which was cut near the ground, and in the fourth the plants were pulled, the roots washed, and set in distilled water. A thousand air-dry seeds from each lot were finally weighed.' In all cases the grain weighed more when permitted to remain in the head than when removed at once, still more when all the stem and leaves were attached, and very much more when the uprooted plant was supplied with water. After-ripening is thus seen to play a very important part in the handling of immature seed.

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[22] Symbola, pp. 67-70; Flora, pp. 508-510.

II.—WEIGHT OF 1000 AIR-DRY KERNELS OF RYE AT DIFFERENT STAGES OF MATURITY.

Experiment conducted by Lucanus.

	I.	II.	III.	IV.	V.
Weight of 1000 air dry kernels, in grams.	Gathered June 28. Grain very small, soft and green.	Gathered July 3. Grain becoming milky.	Gathered July 10. Juices thick and milky.	Gathered July 18. Grain solid, straw yellow.	Gathered July 26. Fully ripe.
Kernels removed at once...	10430	14655	18366	20294	22230
Left in the separated heads..	10575	14830	18510	20302	22250
Left on cut plant..............	11310	14930	18620	20302	22280
Roots in distilled water...	13790	15440	20220	21070	22325

There is a state of over-maturity of seeds, which has importance in this connection. It is well known that the life of the seed is limited; some seeds will not grow after a few weeks or months, although most seeds are good for from one to several years. In all cases the seed gradually loses its vitality, and sooner or later ceases to live, unless in the mean time given the means for germination.

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[23] L. c.

In view of these facts we can better appreciate the importance of the discovery made by Cohn[24] that there is an optimum for most rapid germination which falls, as a rule, just before obvious maturity, (or possibly at the end of the resting stage, where this is very pronounced, a point not yet investigated), and before and after this optimum the germination is slower.

We are thus led to consider the seed as accumulating energy up to the approximate time of its maturity, and then gradually losing this energy so long as it remains an inactive seed; and that the measure of this energy is the vigor of its germination. There is a wealth of data to substantiate this theory of the life of a seed, but which would be burdensome to further present at this time.

Turning now to a more detailed consideration of the deviations from normal development in plants from immature seed, the weakness of the seedlings will be one feature to first attract the attention of the investigator. In a number of trials with green seed of tomatoes, made at various times since 1889, I have found[25] that the young plants are under size; the stems being shorter and cotyledons smaller. They have less strength, and in consequence many perish in the vain attempt to lift the covering of soil. Some are unable to extricate the cotyledons from the ruptured testa, and often perish from this cause, even after having reached the light. If the seeds are germinated between folds of moist cloth or bibulous paper, such miscarriage will show even more clearly. Similar effects were observed by Cohn, in the use of canna seed. He says:[26] "All plants obtained from the youngest seeds were slender and weak, and scarcely progressed beyond the first leaf." Goff,[27] who has made experiments with immature tomato and other seeds at intervals from 1884 to the present time, early noted this characteristic of the seedlings.

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[24] Ich selbst habe bei Canna, Œnothera, Lupinen und anderen ein mittleres Stadium im Reifungsprocesse beobachtet, in dem die Samen sich am schnellsten entwickelten; von da aufwärts und abwärts die reifen und die weniger ausgebildeten schienen mir langsamer zu keimen. Cohn, Flora, xxxii, p. 504.

[25] The data are recorded in the manuscript records of the Indiana Experiment Station, and have not yet been published.

[26] Dagegen waren alle aus den jüngsten Samen gezogenen Pflänchen hinfällig und schwächlich und gediehen kaum über das erste Blatt. Flora, xxxii, p. 501.

The rate of germination is in general slower for immature than for mature seeds. This has been observed by Seyffert, Göppert, Cohn, Toutphöus and others, but this depends upon many internal and external conditions affecting the seed, and it is, therefore, not inconsistent with our theory of the process to find that some observers (Duhamel, Senebier) have noted an increased rate of germination for immature seeds. In an experiment by the writer (manuscript record No. 82) in 1890, tomato plants (24) from the seed of ripe fruit planted in a cold frame, came through the soil in an average of 12 days, plants (5) from seed of half-ripe fruit in 12.2 days, and plants (13) from seed of green fruit in 14.2 days. Other trials with tomato, as well as with peas, wheat, and other kinds, made in the laboratory, using folded cloth, have also given tardy germinations for unripe seeds. Nowacki[28] removed seeds from the heads of wheat when in the milk stage, when turning yellow, and when fully ripe, and sowed carefully selected kernels in the garden (see table III). The rate of germination, judging by the time of appearance of the plants above ground, was much slower for the immature seed, the number on the eleventh day after sowing, being respectively 12, 19, 25.

III.—WHEAT FROM UNRIPE SEED.

Experiment conducted by Nowacki.

Degree of ripeness.	No. seeds.	Germinations.		Stalks.		
		On 11th day.	Total.	Av. No. per plant.	Av. height in cm.	Product of No. by Ht.
In the milk	50	12	45	4.6	128	589
Turned yellow...	50	19	50	5.4	125	675
Fully ripe.........	50	25	50	5.9	121	714

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[27] L. c., iii, p. 225; iv, p. 182.

[28] L. c.

Owing to their weakened condition the plants from immature seed are less able to withstand unfavorable conditions than those from ripe seed, the difference being more marked the younger the seeds. In my own attempts to grow very green tomato seeds in the green-house, fully eighty-five per cent of the plants that had unfolded the cotyledons, perished before reaching the third leaf. Wollny[29] observed a great loss of plants from immature seed of winter rye, taking into account the number of plants growing in the fall and in the following spring, while the plants from ripe seed under the same conditions experienced no loss whatever (see table IV).

IV.—WINTER RYE FROM RIPE AND UNRIPE SEED.

Experiment conducted by Wollny.

Degrees of ripeness.	Number planted.	Growing in fall.	Growing in spring.	Wintered per cent.
Very green..................	100	97	40	41
In the milk.................	100	96	88	91
Pale yellow.................	100	100	100	100
Fully ripe..................	100	100	100	100

(*To be continued.*)

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[29] L. c.

THE EFFECT OF FEMALE SUFFRAGE ON POSTERITY.

BY JAMES WEIR, JR.

The greatest, best, and highest law of Higher Civilization is that which declares that men should strive to benefit not himself alone, but his posterity.

I. THE ORIGIN OF THE MATRIARCHATE.

In the very beginning woman was, by function, a mother; by virtue of her surroundings, a house-wife. Man was then,